Angular Signature Retrieval and Comparison with Spectral Signatures from AirMISR Data

S. A. W. Gerstl, W. Gebauer, C.C. Borel, C. Dochitoiu
Los Alamos National Laboratory, NIS-DO, MS-C323, Los Alamos, N.M. 87545, USA.
Tel. (505)667-0952, Fax (505)667-3815, e-mail: sig@lanl.gov

ABSTRACT

Most image classification techniques are built on the spectral variability of the data, which is the primary information retrieval mechanism for nadir-acquired images. However, with the advent of simultaneous multi-directional observations, like with the Multi-angle Imaging SpectroRadiometer (MISR) instrument on NASA's Earth Observing System (EOS), to be launched on the Terra platform in July 1999, the directional variability of the data can also be exploited. The additional information content in the directional data, which is called an angular signature, is expected to be particularly useful in the identification and classification of vegetated land surfaces because it derives from the degree of how much shadowing within a 3D canopy may be detected [1]. The shadow fraction of a vegetated surface element as seen from a particular view direction contains unique information about the canopy structure and architecture when observed from multiple directions; this information does not manifest itself in any spectral signature.

INTRODUCTION

The data for both the multi-spectral as well as the multi-directional observations was acquired by the airborne version of MISR, the Multi-angle Imaging SpectroRadiometer (AirMISR). The AirMISR sensor has 9 different view directions: four in forward, one in nadir, and four in the aft direction along its track, and simultaneously 4 spectral bands in the visible and near infrared in each camera. This unique remote sensing technique allows the application of classification algorithms with respect to the spectral as well as the directional variables. We can then make a direct comparison between spectrally and directionally classified images acquired during one overpass and using the same instrument. Because of this observation technique the additional information obtained by the nine multi-directional camera views can be compared with the information given solely by the 4 spectral bands.

Only 2 data sets of AirMISR data that contain vegetated surfaces have thus far become available for analysis: an image over Moffett Field, California, acquired in August 1997, and an image over Pasadena, acquired in December 1998. Performing a spectral signature classification of the nadir images of each of the 2 data sets, using the Normalized Difference Vegetation Index (NDVI > 0.055), showed that the Moffett Field image contained less than 5% vegetated areas, while the Pasadena image showed a 15% vegetated area fraction in the image. In addition, some image registration difficulties in the Moffett Field data set eliminated it as the basis for further analysis in our search for angular signatures of vegetated areas.

PRINCIPAL COMPONENT ANALYSIS

Concentrating on the Pasadena image, see Fig.1, we performed a Principal Components (PC) analysis on the data set to determine its uncorrelated information content. Data from only 7 of the nine AirMISR cameras were used because the most oblique forward and aft-looking D cameras (70.5 degree view zenith angle) contained very large amounts of atmospheric scattering and very long shadows in the image, which led to co-registration difficulties; they were thus omitted from the analysis.

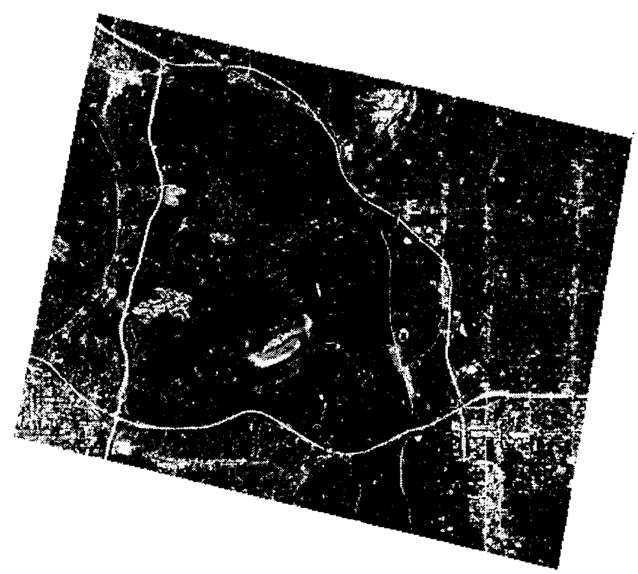

Figure 1: AirMISR image over Pasadena, California, acquired December 1998, solar zenith angle 57 degrees, nadir (670 nm) component shown.

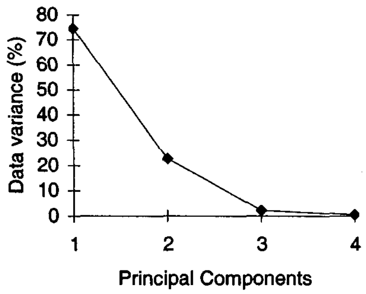

Figure 2: Principal Components data variance in the 4-channel nadir image, spectral information only.

Results from the PC analysis are shown in Figs.2 and 3. Taking only the spectral information from the 4 spectral bands in the nadir image, Fig.2, we detect only 2 significant principal components containing more than 90% of the uncorrelated information. Taking the data from all 7 observation directions in each of the 4 spectral bands, the PC analysis identifies 8 significant Eigenvalues for the same 90% decorrelation threshold. Thus we expect to identify additional significant information in the angular signatures.

The AirMISR data were acquired under cloud-free clear atmospheric conditions with good visibility from about 20 km altitude, and this PC analysis was carried out for the data uncorrected for atmospheric effects.

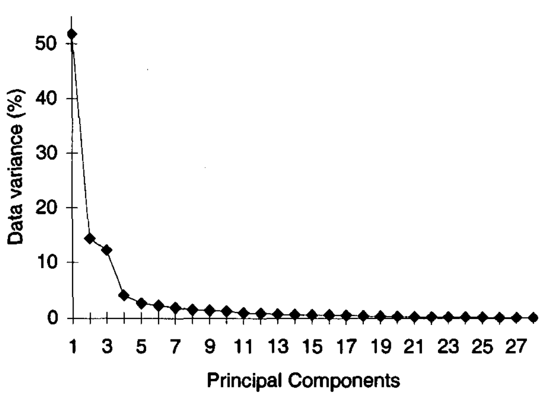

Figure 3: Principal Components data variance in 4 spectral bands plus 7 observation directions (4·7 = 28 dimensions).

ANGULAR SIGNATURE RETRIEVAL

On these atmospherically uncorrected data we then attempted to perform an unsupervised classification of the image data which failed because too many classes were identified due to the extreme spatial heterogeneity in the image. Such spatial heterogeneity is enhanced due to missregistration effects that create many mixed pixels at surface boundaries when the images from the 7 different view directions cannot be perfectly 'laid on top of each other'. This, of course, can happen easily in aircraft data due to instrument jitter.

A supervised classification was then carried out where we selected 3 vegetated areas, a large building roof, and a parking lot, as training sets, which we identified by visual inspection in the nadir image, Fig.1. In an attempt to minimize the atmospheric perturbations in the 'top-of-the-atmosphere' (TOA) images, we restricted ourselves initially to the red band (670 nm) data with all 7 observation directions. Fig.4 shows the angular signatures of the 5 selected training classes (mean vector of the minimum distance criterion with a standard deviation of 0.005 in each dimension). The 3 vegetation classes are fairly similar among each other but distinctly different from the 2 non-vegetated classes. All signatures show characteristic bowl-shapes that are enhanced toward the +60 degree Ca-camera direction which is closest to the hotspot. The BRDF slice that is measured by this AirMISR acquisition is off-set by a view azimuth angle of 15 degrees away from the principal plane.

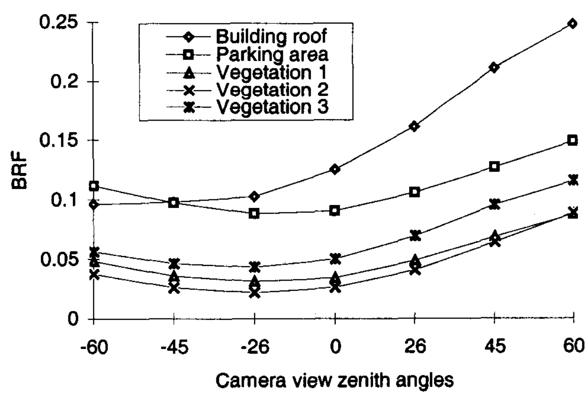

Figure 4: BRF angular signatures at top-of-atmosphere in the red band for 5 training classes.

ATMOSPHERIC CORRECTION

Since no quantitative data about the atmospheric conditions during the data acquisition have been available, we could not perform a rigorous atmospheric correction on these multi-angular data. Carrying out an approximate atmospheric correction (with the 6S code) for the Rayleigh scattering component alone, yielded the approximate top-of-canopy angular signatures of the 3 vegetated areas shown in Fig.5.

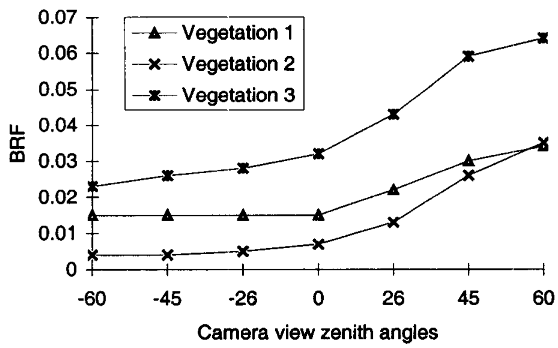

Figure 5: BRF angular signatures for 3 vegetation classes at top of the canopy, atmospherically corrected for Rayleigh scattering only.

Realizing that these are only first-order approximations the result shows at least the discernability of these 3 vegetation classes. We can also conclude that good atmospheric corrections are necessary to identify top-of-the canopy angular signatures that may be diagnostic for different vegetation types.

COMPARISON

Combining the 3 selected vegetation training classes (from the atmospherically uncorrected data) into one we obtained an angular-signature classified image (Fig.6) that can be compared with an NDVI-classification (Fig.7) of the nadir image (threshold of 0.055). Visual inspection shows similarities between the angular-signature classified image and the NDVI-classified image: 42% of the pixels are common, while 58% exclude each other.

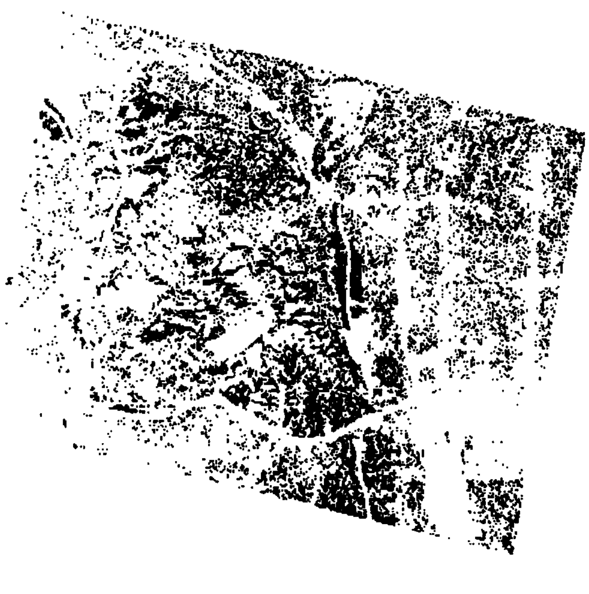

Figure 6: Angular-signature classification (3 classes combined) using only the 670 nm band in 7 camera angles.

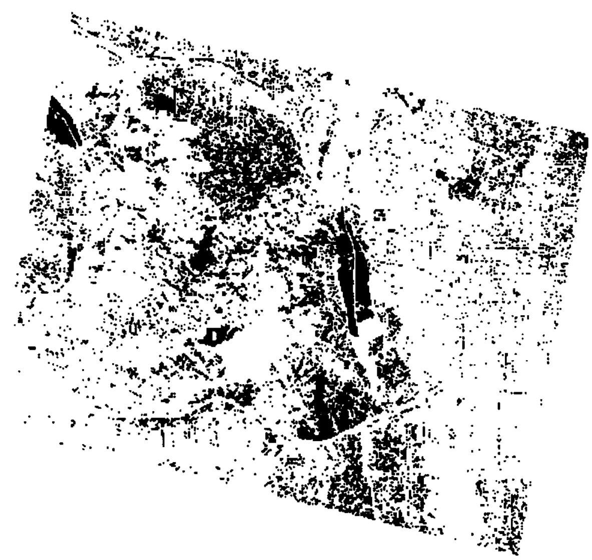

Figure 7: NDVI classification (NDVI > 0.055) calculated out of the red (670nm) and near-infrared (865nm) channels.

CONCLUSION

The angular signature retrieval was only conditionally successful. Without good atmospheric corrections and good scene registrations of the multi-angular images, an unsupervised angular signature classification was not possible. Supervised classification was possible, even for the top-of-the atmosphere data. However, these results are scene-dependent and are biased by the availability of only one data set (the Pasadena AirMISR data from December 1998), which was suboptimal for this analysis: only 15% vegetation area cover, extreme spatial heterogeneity, low sun angle, and missing atmospheric data for a reliable atmospheric correction.

REFERENCES

[1] S.A.W. Gerstl, "The Angular Reflectance Signature of the Canopy Hotspot in the Optical Regime", Proc. 4th Int. Coll. on Spectral Signatures of Objects in Remote Sensing, Aussois, France, Jan. 1988. ESA Report, SP-287, 129-132 (April 1988).